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Communications Division

GENERAL DOCUMENT
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MILITARY APPLICATIONS FOR THE AUSSAT L-BAND TRANSPONDER

by

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SUMMARY

The Australian Department of Defence has made a decision to investigate the use of the AUSSAT L-band transponder to support communications to tactical platforms. This document addresses a number of technical issues and options associated with Defence use of the AUSSAT B-series L-band transponder.

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CONTENTS

FIGURES

† **MOBILESAT™** is an Australian Registered Trademark of AUSSAT Pty Ltd.

ABBREVIATIONS

ADF	Australian Defence Force
AUSSAT	Australian (Domestic Communications) Satellite
CUG	Closed User Group
DMCM	Defence Mobile Communications Network
EIRP	Effective Isotropic Radiated Power
FANS	Future Air Navigation System
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
GPS	Global Position System
INMARSAT	International Maritime Satellite
LPC	Linear Predictive Coding
MCES	Major City Earth Station
NMS	Network Management Station
PSTN	Public Switched Telephone Network
RDSS	Radio Determination Satellite Service
RF	Radio Frequency
SCPC	Single Channel per Carrier
TDM	Time Division Multiplexed
TDMA	Time Division Multiple Access
UHF	Ultra High Frequency

1 INTRODUCTION

Three first generation AUSSAT spacecraft are stationed off the east coast of Australia at 156°E (A2), 160°E (A1) and 164°E (A3). Each spacecraft carries fifteen Ku-band (14/12 GHz) transponders which may be connected to a number of transmit and receive beams, including two national receive beams, two national downlink beams and four regional downlink beams covering South Eastern, North Eastern, Central and Western Australia.

The A1 and A2 spacecraft were launched via the Space Shuttle on 27 August 1985 and 27 November 1985 respectively and have lifetimes of approximately 7.5 years. The A3 spacecraft was launched via the Ariane expendable launch vehicle, however, due to technical problems encountered at that time with the Ariane third stage, the launch did not occur until 16 September 1987. Since the Ariane launch site at Kourou in French Guiana is closer to the equator than Cape Kennedy, there was a considerable saving in station keeping fuel during launch, resulting in an increased lifetime for the A3 spacecraft of approximately 10 years. Consequently, the A3 spacecraft is not due to be replaced until 1997.

The AUSSAT A1 and A2 spacecraft will be replaced in 1992 by two AUSSAT second generation B-Series spacecraft. These spacecraft are being manufactured by Hughes Aircraft and are based on their body-stabilised HS601 spacecraft bus. The first spacecraft is due for launch in May 1992 via a Chinese Long March expendable launch vehicle and the second is scheduled for launch in August 1992. Each spacecraft will carry fifteen 50 W high-power, 54 MHz bandwidth, Ku-band transponders as well as a 150 W L-band (1.6/1.5 GHz) transponder. The Ku-band transponders will provide similar coverage areas to the first generation spacecraft with the exception that there will be a high performance beam providing high downlink EIRP over densely populated areas of Australia and a spot beam covering New Zealand. The L-band transponder is designed to operate in a hub configuration and provide communications to mobile terminals operating within Continental Australia.

This paper addresses a number of technical issues and options associated with Defence use of the AUSSAT B-series L-band transponder.

2 AUSSAT B-SERIES L-BAND TRANSPONDER

The AUSSAT B-series L-band transponder is designed to support communications to a large population of commercial mobile terminals operating within Continental Australia. Aussat Pty Ltd have called their L-band network **MOBILESAT™**. Mobile terminals operate in a hub configuration with uplinks (inbound links) and downlinks (outbound links) at L-band and the corresponding uplinks and downlinks to the hub station at Ku-band. The AUSSAT B-series outbound L-band transponder Effective Isotropic Radiated Power (EIRP) contours plotted on a Mercator projection are shown in Figure 1 with a typical downlink EIRP of 47 dBW over Continental Australia. Figure 2 shows the inbound L-band transponder figure of merit

contours (G/T) on a similar projection. Brief specifications for the L-band transponder are shown in Table 1. Further detailed specifications are contained in Enclosure 3, Vol 3 of reference 1.

Table 1 **AUSSAT B-Series L-band transponder specifications**

Outbound transponder	
Downlink frequency	1545 - 1559 MHz (Right Hand Circular Polarisation)
Uplink frequency	14 011.5 - 14 025.5 MHz (Linear, Vertical Polarisation)
Bandwidth	14 MHz
EIRP (Maximum)	47 dBW (see Figure 1)
System Noise Temperature	1257° K
Inbound transponder	
Uplink frequency	1646.5 - 1660.5 MHz (Right Hand Circular Polarisation)
Downlink frequency	12 263.5 - 12 277.5 MHz (Linear, Horizontal Polarisation)
Bandwidth	14 MHz
Uplink frequency (RDSS)	1610.0 - 1626.5 MHz (Right Hand Circular Polarisation)
Downlink frequency (RDSS)	12 227.0 - 12 243.5 MHz (Linear, Horizontal Polarisation)
Bandwidth (RDSS)	16.5 MHz
G/T	-2 dB/K (see Figure 2)
System Noise Temperature	794° K

3 MOBILESAT™ †

The following description of the **MOBILESAT™** network was extracted from an early publicly released version of the "AUSSAT **MOBILESAT™** System Description". It therefore contains a number of discrepancies but is included to provide background information for later discussions on Defence use of the AUSSAT L-band transponder. More detailed information on the **MOBILESAT™** network is contained in the November 1991 release of the "AUSSAT **MOBILESAT™** System Description" which may be purchased from Aussat Pty Ltd. Refer to Enclosure 2, Vol 3 of reference 1 for details on technical documentation available from Aussat Pty Ltd.

† MOBILESAT™ is an Australian Registered Trademark of AUSSAT Pty Ltd.

3.1 Transponder channel assignments

In the commercial **MOBILESAT™** system, the transponder bandwidth of 14 MHz is divided using Frequency Division Multiple Access (FDMA) techniques into channel increments of 2.5 kHz. The nominal channel bandwidth is defined as 5 kHz for all **MOBILESAT™** carriers with the exception of the Outbound Time Division Multiplexed (TDM) signalling channel transmitted by the Network Management Station (NMS) which is allocated a channel bandwidth of 20 kHz. User access within the allocated channels is by either Single Channel per Carrier (SCPC) for communications services or by a range of time division sharing for signalling and messaging services.

3.2 Network management station

The Network Management Station is the key element in the **MOBILESAT™** system. The NMS is responsible for the network control and allocation of all circuit switched channels for voice/data communication as well as the transfer of user messages. Another NMS function is the control of the network configuration and allocation of system resources to meet traffic loads. The majority of the system intelligence resides within the NMS.

The **MOBILESAT™** network will be implemented with two NMSs; the primary centre is located at the AUSSAT, Belrose Major City Earth Station (MCES), Sydney and the secondary centre will be located elsewhere in Australia. Primary and secondary centres will provide site diversity therefore maximising system availability, and in particular providing protection against Ku-band rain fades. At any one time, one of the NMS centres will be configured as the primary network control centre with the other NMS acting as the secondary back up. The NMS will be integrated into existing AUSSAT Ku-band earth station facilities.

3..3 Service types

Three generic communications service types have been developed to operate on the **MOBILESAT™** system:

(i) A Telephony service that provides demand assigned capacity between one or more mobile terminals and a nominated base station or mobile terminal.

(ii) A Mobile Radio service that provides a half duplex mobile radio network; an extension of the Telephony service.

(iii) A Messaging service that provides an ancillary messaging capability between a mobile terminal and Dispatch Centre via the NMS.

Private networks will use the Mobile Radio Service and will be able to make a number of different calls based on the Closed User Group (CUG) concept. CUGs will be user defined and the number of different CUGs held in the Base Station will be up to the

users discretion. Call configurations available to Private Network customers are extremely flexible;

- One-to-one calls, either from mobile-to-base, or from mobile-to-mobile (double hop);
- Group calls where a number of remote terminals enter into a conversation with their own inbound channel.
- Shared group calls where remote terminals share a common inbound channel.
- Broadcast calls; either a broadcast from the base, a broadcast from a remote terminal, or broadcast a conversation with a CUG. Remote terminals listening-in to a broadcast conversation can request a channel and enter into the broadcast conversation.

3.4 NMS to outbound signalling channel

This channel will transmit continuously at a symbol rate of 9600 bits/s and is monitored at L-band by all active mobile terminals not engaged in communication over an allocated SCPC channel.

The NMS outbound signalling channel will be based on a highly structured format based on a 110 ms frame length and comprising the following components:

(i) a frame unique word of 32 bits, sent at the start of every frame for frame synchronisation.

(ii) eight TDM packets containing system command, control information plus messaging data to be addressed to one or more terminals.

The TDM packets are based on a signalling unit with a length of 96 bits resulting in a coded TDM packet that is 128 bits long.

There is a proposed "super frame" format comprising 10 TDM frames, giving a frame length of 1100 ms. The first frame is a Bulletin Board with the remaining 9 frames used for general signalling and data messaging. It is proposed that the signalling information is transmitted 3 times to maximise the probability that the mobile terminal receives the signalling information correctly.

3.5 Mobile to NMS inbound signalling channel

Two discrete channel types are proposed to transfer signalling and acknowledgement information plus messaging data from a mobile terminal to the NMS.

(i) Channels for call request and unsolicited messaging are transmitted in random access burst mode, using a slotted ALOHA procedure, at a symbol rate of 2400 symbols/s from the terminal.

(ii) Channels for acknowledgement of NMS commands and polled messages are transmitted in a preassigned TDMA burst mode with the slot allocation dependent on the slot occupied by the command to be acknowledged in the outbound TDM frame.

As the inbound channels are synchronised to the outbound TDM channel they have a common frame length of 110 ms. The inbound frames consist of 30 ms guard time, a 32 bit preamble, a 32 bit unique word and a 128 bit coded signalling packet.

4 DEFENCE USE OF THE L-BAND TRANSPONDER

The following sections address a number of technical options for Defence use of the AUSSAT L-band transponder.

4.1 Defence access to MOBILESAT™

One option is to fit standard **MOBILESAT™** terminals to Defence tactical platforms as shown in Figure 3. Since the **MOBILESAT™** access protocols and modulation type are not compatible with the INMARSAT L-band transponder it also may be necessary to fit INMARSAT compatible terminal equipment when operating outside of the AUSSAT footprint. It should be noted that INMARSAT imposes restrictions on Defence use of its communications assets.

One advantage of using standard **MOBILESAT™** access protocols is that the mobile terminal uplink frequency would be allocated dynamically in the transponder and may therefore be difficult to distinguish from other commercial accesses. In order to increase the coverage area it may be necessary to increase the outbound link EIRP to Defence platforms. This would highlight their presence in the transponder amongst standard **MOBILESAT™** accesses. Also, if the uplink power of the Defence tactical platform inbound link is not varied to compensate for variation in the AUSSAT L-band receive antenna gain, then it may be possible to identify the access in the transponder.

If L-band transponder power to Defence platforms is increased to enhance the coverage area, then the L-band downlink power of the signalling channel must also be increased to provide a similar coverage area. This would improve the signalling channel signal-to-noise for **MOBILESAT™** terminals operating within Continental Australia and may result in a cost penalty for Defence. The cost of communicating via a standard **MOBILESAT™** terminal, including access to the terrestrial Public Switched Telephone Network (PSTN), is estimated by AUSSAT to be $1.20 per minute. Based on this cost, if satellite power allocated to Defence terminals was increased by a factor of four over a standard **MOBILESAT™** terminal, then the cost to Defence could be in excess of $5 per

minute taking into account the increased satellite power to support the signalling channel.

One disadvantage of this option is that the **MOBILESAT™** system supports two data rates, ie 6600 bits/s for voice and 2400 bits/s for data. It is therefore not possible to take advantage of increased coverage area by reducing the data rate, for example to 600 or 75 bits/s.

Encryption of the traffic poses a significant problem. If voice is vocoded at 2400 bits/s and encrypted, then multiple 2400 bit/s lines would be required between the AUSSAT hub station and a Defence installation equipped with a similar number of cryptographic devices. The number of lines/cryptographic units would be at least equal to the maximum number of simultaneous accesses allowed in the transponder for Defence purposes. It is envisaged that with this option the maximum number of simultaneous Defence accesses would be controlled by the AUSSAT hub station.

4.2 Integrated AUSSAT and defence hub stations

Another option is for Defence to install its own hub station and to operate in conjunction with the AUSSAT hub station by allowing the AUSSAT hub station to control the signalling protocols and for the Defence station to receive the traffic as shown in Figure 4. This has the advantage that the data rates on the link do not need to conform with those of the **MOBILESAT™** network and a number of the encryption problems may be overcome. Reducing the data rate would enhance the coverage area.

One disadvantage of this system is that the Defence station may need to be as complex as the AUSSAT hub station to be compatible with it. Both software and hardware modifications could be necessary to interconnect the two hub stations for the AUSSAT hub station to inform the Defence station of the allocated transmit and receive frequencies.

Another reason for using the AUSSAT hub station to dynamically allocate frequencies would be to disguise the Defence accesses amongst the commercial accesses. If the Defence outbound link is operating at increased downlink power to increase the coverage area then it could be detected. Equally, if the Defence inbound terminal uplink EIRP is not varied in harmony with the change of the AUSSAT L-band receive antenna gain contour then it too would be identifiable.

4.3 Dedicated defence hub station

Another option is for Defence to install its own hub station and lease a segment (power and bandwidth) of the AUSSAT L-band transponder as shown in Figure 5. The AUSSAT hub station would be programmed not to allocate commercial **MOBILESAT™** accesses in this part of the transponder and Defence would appear to have a dedicated transponder. It would therefore be possible for Defence to establish its own network protocols ranging from simple through to complex. Leasing a fixed part of the transponder may make it vulnerable to electronic counter-measures. An alternative

might be to lease separate channels distributed throughout the transponder. The channels may not necessarily be fixed in frequency but allocated dynamically by the MOBILESAT™ NMS.

4.3.1 Use of existing military radios

One of the concerns expressed by some personnel within Air Force has been the problems associated with fitting and integrating additional radios onboard military aircraft. One simple, cost-effective approach to the introduction of L-band satellite communications is to develop an applique unit for either existing or proposed (eg ARC 187) UHF radios to convert the RF output from UHF to L-band. Navy has a large inventory of satcom compatible AN/WSC-3 UHF radios which may also be fitted with L-band applique units.

4.3.2 L-Band antenna considerations

L-band satellite communications antennas have been or are being developed for a broad range of commercial mobile platforms including ships, aircraft, trucks, cars, etc. One of the highest risk areas facing Defence application of L-band satellite communications is fitting commercial antennas to military platforms.

The INMARSAT L-band satellite communications network has been in service for many years and provides global communications for commercial shipping. INMARSAT has developed a number of standard access protocols and terminals to support voice and data. These protocols and associated terminals are designated A, B, C and M. Type A and B systems have steerable parabolic reflector antennas up to 1 m in diameter and designed to support both voice and data services. In the longer term, Type A terminals will be superseded by Type B terminals. Type C terminals have lower gain omni-directional antennas and are designed to support data only.

Research and development is being undertaken by a number of companies throughout the world into L-band antennas for large commercial aircraft. It is intended that these antennas will operate through the INMARSAT network to support the Future Air Navigation System (FANS). The Global Position System (GPS) operates in a similar frequency band as L-band satellite communications, hence an aircraft fitted with an L-band antenna is able to monitor its position in three dimensions to an accuracy of less than 100 m. Aircraft position will be automatically transponded via the INMARSAT L-band satellite communications network to air traffic control centres located at strategic points in the network. Aircraft position will thus be known to a high degree of accuracy as it travels around the globe. Also, L-band satellite communications will provide the ability to monitor performance parameters onboard the aircraft as well as provide passenger services such as telephone and facsimile.

Two basic types of antennas are being developed for large commercial aircraft; the omni-directional antenna (0 dBi gain) for low data rate applications and electronically/mechanically steered high gain antennas with gains of typically 12 dBi to support both voice and data services. Commercial aircraft are not subjected to the levels of stress associated with military aircraft and hence without additional engineering and qualification these antennas may only be fitted to the larger class of military aircraft with a commercial pedigree, eg B707, P3C, F900 and C130. Both mechanically-steered and electronically-steered antennas are being developed for aeronautical applications. **It should be noted that some of these antenna configurations exhibit a "keyhole effect" whereby antenna gain cannot be maintained over the nose and tail of the aircraft.** This has some important implications in attempting to extend the L-band transponder coverage area for aeronautical terminals operating beyond Continental Australia, particularly in the Indian Ocean.

4.3.3 Network architecture considerations

The total inventory of aircraft considered feasible to fit L-band satellite communications antennas is limited to approximately 55. Since only a small percentage of these aircraft would be operational at any one time and requiring communications then a simple networking architecture may be sufficient. This may reduce significantly the cost of the ADF hub station.

5 TECHNIQUES FOR INCREASED COVERAGE AREAS

The AUSSAT L-band transponder is designed to support mobile communications within Continental Australia. **MOBILESAT™** terminals are designed to operate within the 47 dBW EIRP contour shown in Figure 1.

The coverage area for Defence applications may be increased by employing the following techniques:

5.1 Low data rate vocoded voice

The **MOBILESAT™** system is designed to provide commercially acceptable voice grade services. To achieve this, vocoders operating at data rates of 4800 bits/s have been chosen. When combined with Forward Error Correction (FEC) coding and overheads, the transmission rate over the link is increased to 6600 bits/s Use of lower quality voice for Defence applications such as 2400 bits/s Linear Predictive Coding (LPC) combined with increased FEC coding rates such as rate 1/3 or rate 1/2 convolutional encoding and Viterbi decoding has the potential to provide 5-6 dB of improvement. This would allow a Defence terminal to operate out to the 41-42 dBW L-band EIRP contour for the same satellite power as a standard **MOBILESAT™** terminal.

5.2 Utilisation of link margin

Downlink satellite power to **MOBILESAT™** terminals has been designed to provide sufficient link margin to compensate for limited fading caused by foliage, buildings, etc. Typical link margins of 5 dB have been proposed. Aircraft and ships would not require the same level of link margin hence this reduced level of link margin would translate into increased coverage area. For example, an airborne terminal may require a link margin of only 2 dB.

5.3 Mobile terminal figure of merit

The figure of merit or G/T for an earth terminal is given by the earth terminal receive antenna gain divided by the system noise temperature. Figure of merit is an engineering term which is a measure of earth terminal efficiency in terms of satellite power to support a given data rate. All link calculations for AUSSAT **MOBILESAT™** terminals are based on a terminal G/T of approximately -17 dB/K. Typical gain of an aeronautical L-band antenna is 12 dBi. Assuming a system noise temperature of 400° K, the G/T of the aeronautical terminal is -14 dB/K resulting in a 3 dB improvement over a conventional **MOBILESAT™** terminal. Aeronautical terminals should therefore be capable of operating in an area defined by the 44 dBW EIRP contour in Figure 1 for a satellite power equivalent to one **MOBILESAT™** terminal. In the case of shipboard terminals where an INMARSAT Type A stabilised parabolic antenna up to 1 m in diameter could be used, the G/T is typically -4 dB/K, resulting in a 13 dB improvement over a **MOBILESAT™** terminal. Hence, a shipboard terminal of this type could operate within the 34 dBW contour for a satellite power equivalent to one **MOBILESAT™** terminal.

In summary, for the same satellite power as a **MOBILESAT™** terminal and taking advantage of LPC and reduced link margin, an aircraft could support secure voice within the 36 dBW AUSSAT L-band EIRP contour whereas a ship fitted with an INMARSAT Type A antenna could operate within the 26 dBW EIRP contour.

5.4 Increased satellite power

Downlink power allocated to **MOBILESAT™** terminals is controlled by the AUSSAT hub station and set at approximately 24 dBW for each access. In effect the transponder is a linear amplifier and the L-band satellite downlink power is controlled by Ku-band uplink RF power from the hub station. Increasing the Ku-band uplink power for example by a factor of 4 (6 dB) would result in an increased L-band downlink power of 4 or 6 dB. When applied to the Defence Hub station this would enable Defence terminals to operate a further 6 dB out on the EIRP contours. These results are summarised in Table 2.

Table 2 **AUSSAT L-band transponder EIRP contour for defence secure voice**

	L-BAND TRANSPONDER POWER EQUIVALENT TO	
	1 MOBILESAT™ ACCESS EIRP CONTOUR	4 MOBILESAT™ ACCESSES EIRP CONTOUR
AIRCRAFT (1)	36 dBW	30 dBW
SHIP (2)	26 dBW	20 dBW

Notes: 1. Fitted with a 12 dBi steerable antenna.
2. Fitted with an INMARSAT Type A antenna.

5.5 Reduced data rate

In most cases it is assumed that the Defence network would support secure voice operating at a minimum data rate of 2400 bits/s. Since satellite power is proportional to data rate, reducing the data rate by a factor of 10 to 240 bit/s, would enable the same terminal to support data out to an EIRP contour 10 dB less than shown in Table 2. Some caution should be heeded when reducing data rate because of limitations caused by phase noise in the L-band transponder translation frequency oscillator and ground terminal local oscillators.

5 SUMMARY

It can be seen that the combination of reducing data rate, increasing rates of forward error correction coding, increased earth terminal figure of merit and operating at reduced link margin all contribute to increase the effective coverage area of the AUSSAT L-band transponder.

6 ACKNOWLEDGEMENTS

Some sections describing the AUSSAT **MOBILESAT™** system have been extracted from a publicly released version of the "AUSSAT **MOBILESAT™** System Description".

REFERENCE

1. "Defence Mobile Communications Network (DMCN) Implementation Study - Request for Tender (RT63/91173W-002)", Vol 1 to 3, 27 Nov 1991.

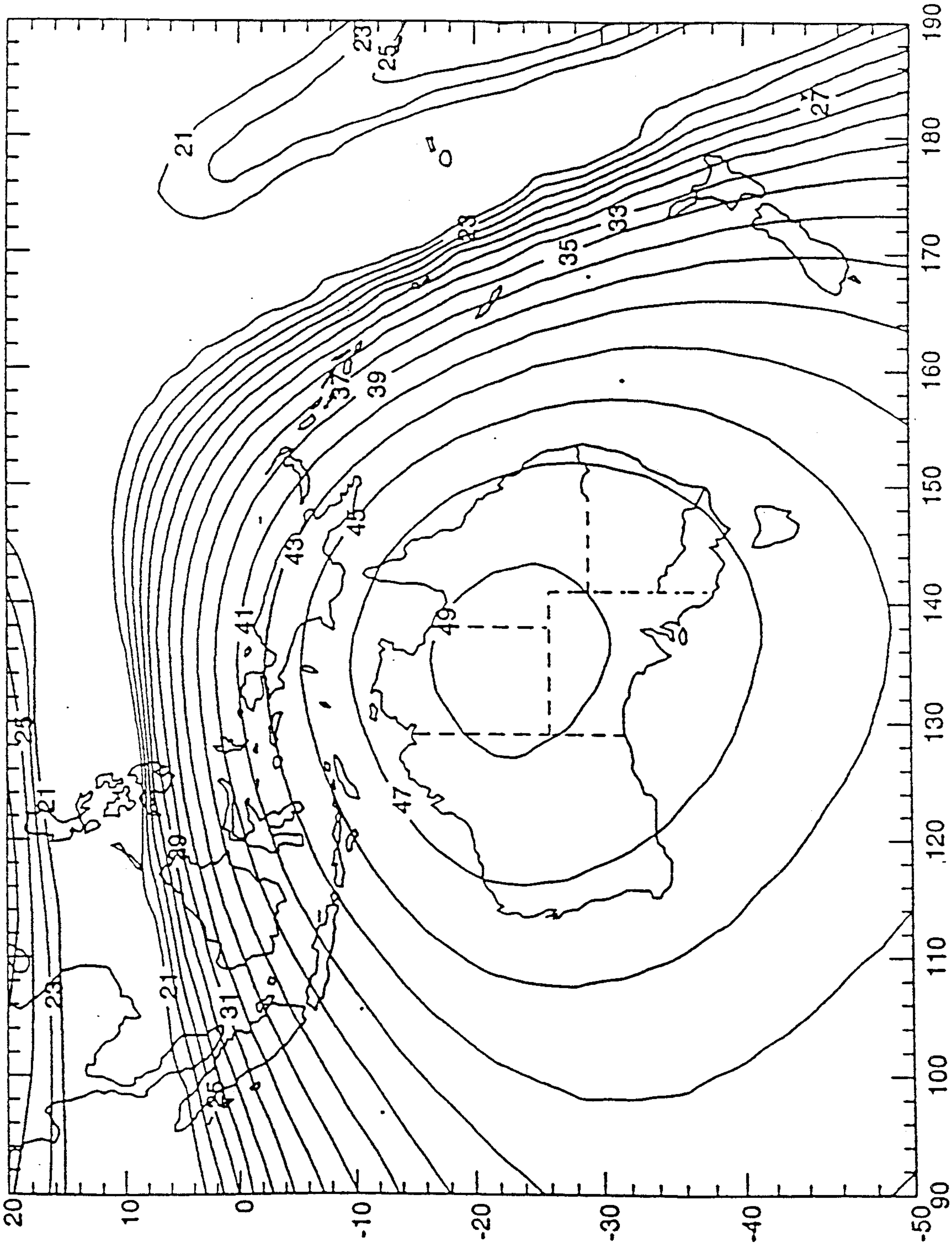

Figure 1 **AUSSAT L-band transponder EIRP contours**

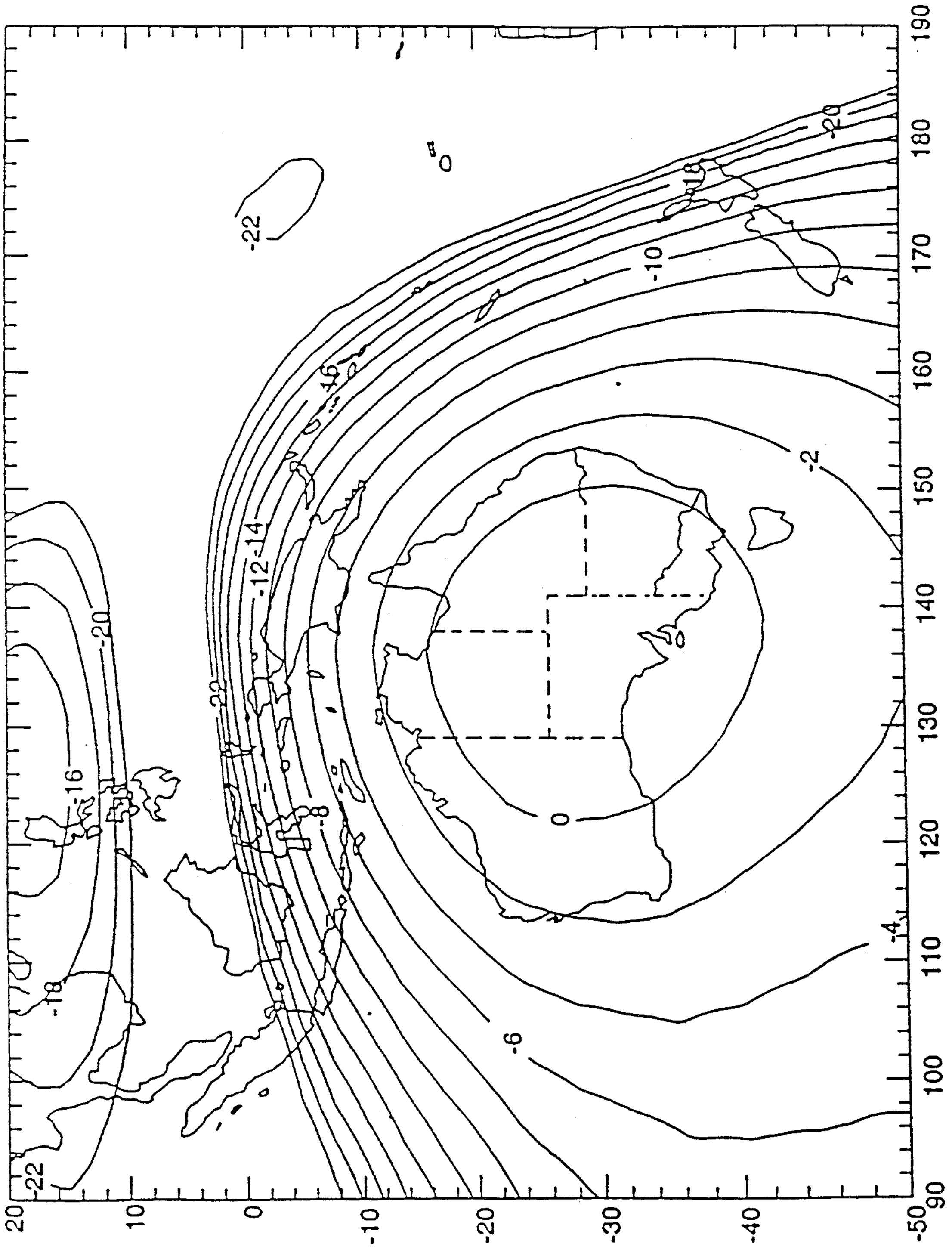

Figure 2 **AUSSAT L-band transponder G/T contours**

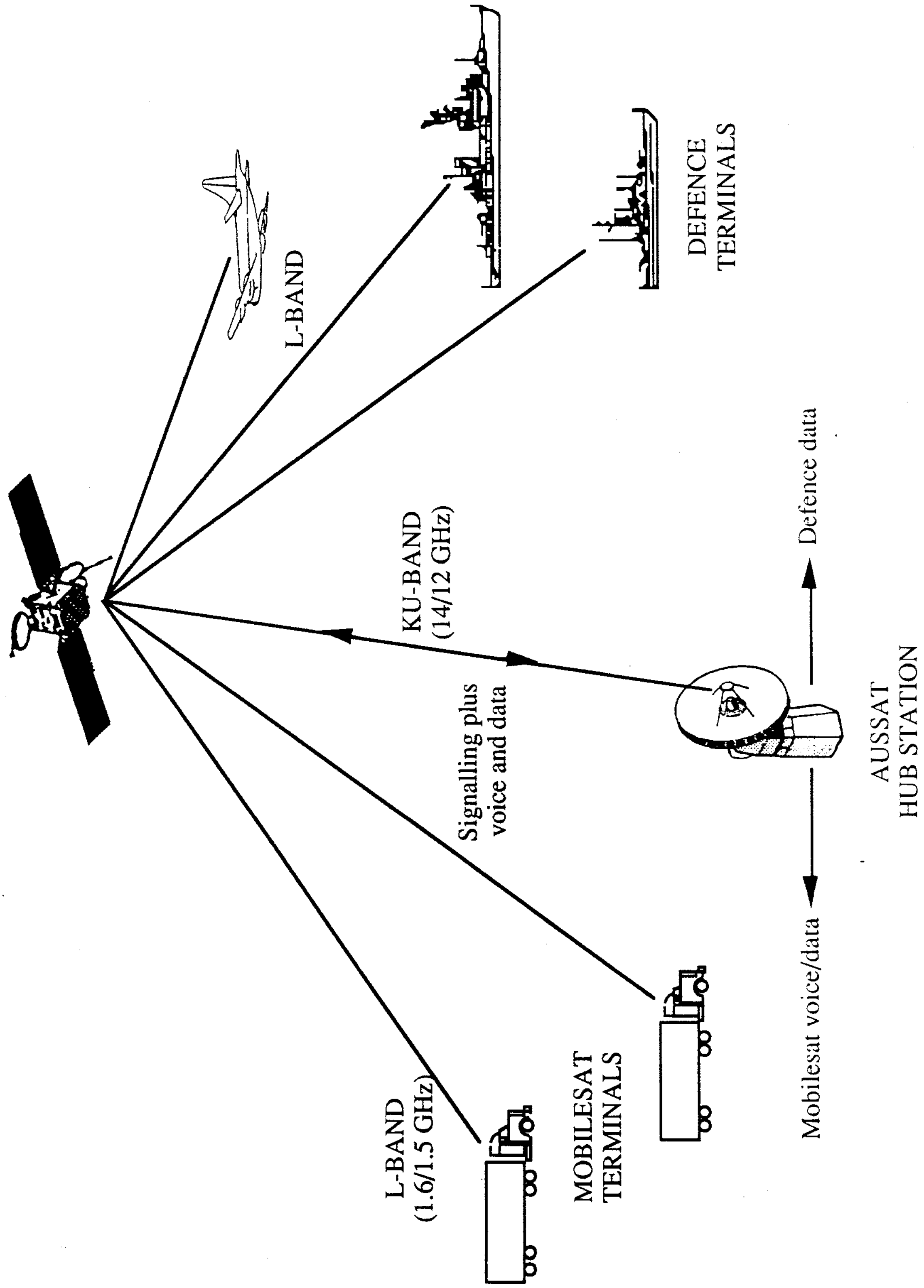

Figure 3 **Defence integration into MOBILESAT™**

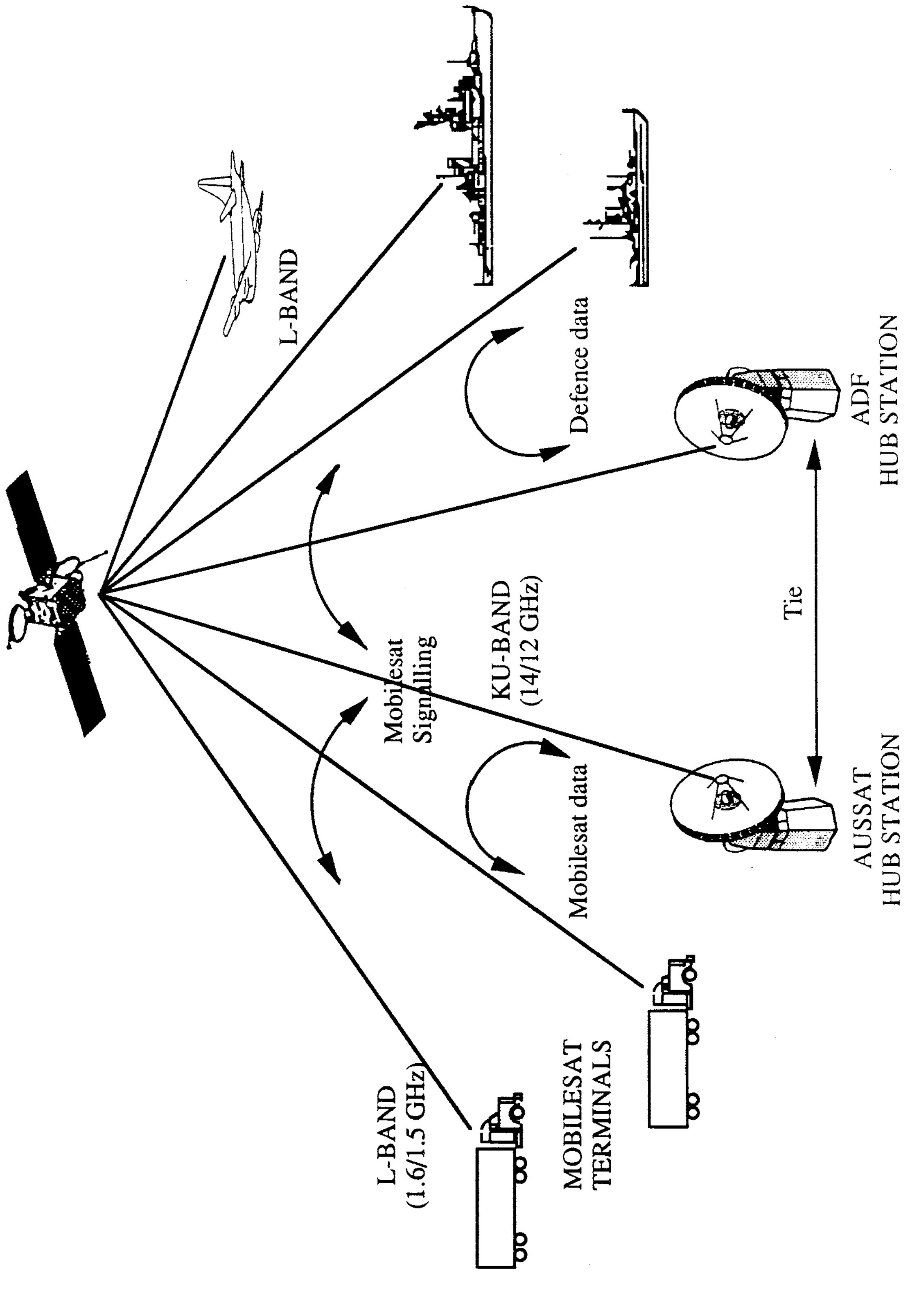

Figure 4 **Defence network with common signalling protocols**

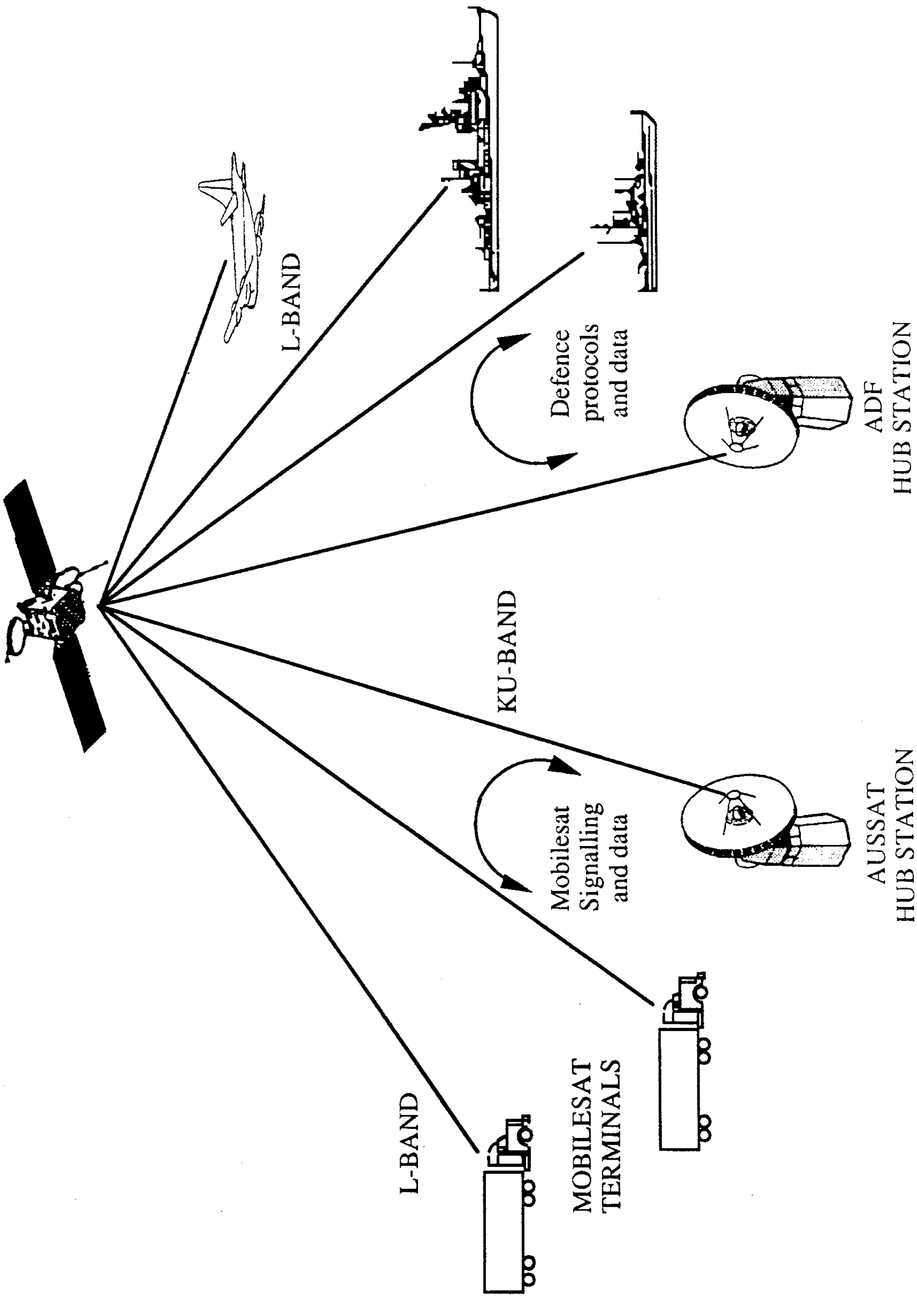

Figure 5 **Defence private L-band network**

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16. Abstract

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